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H2E EEA  
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(56) Documents Cited

GB 2165104 A EP 0439137 A US 5435732 A  
IBM Technical Disclosure Bulletin Vol. 37, No.09,  
September 1994 page 243

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Selected publications

(54) Abstract Title

Electrical connector or connection with concave ball-receiving site

(57) A substrate, such as an IC module 40 (figure 2), is terminated to another substrate, such as a printed circuit board 50, by means of a plurality of concave ball-receiving sites 44 formed in the module which receive balls 30, eg solder balls, to establish an electrical interface. The opposite side of the ball connects with a pad 52 of the PCB. Two parts 70, 80 (figure 4) of a connector as shown, have ball-receiving cup sections 72, 82. Balls therein make a PCB interface.

FIG. 2

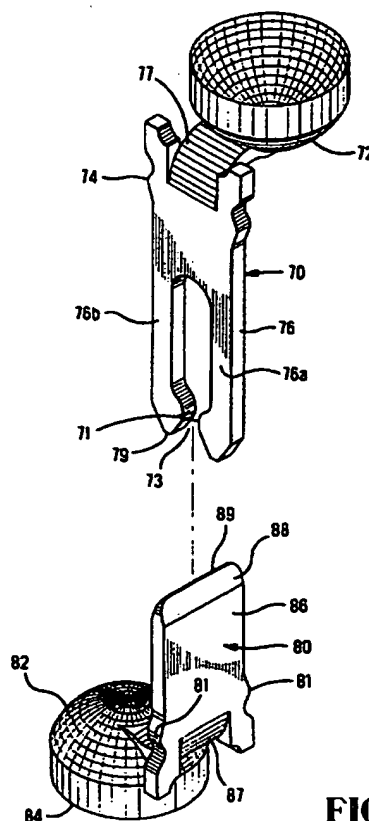
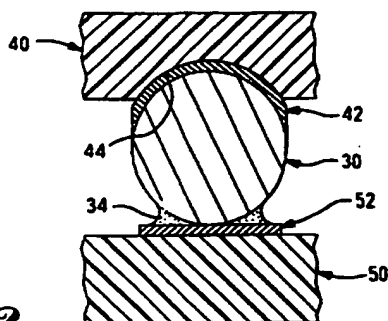


FIG. 4

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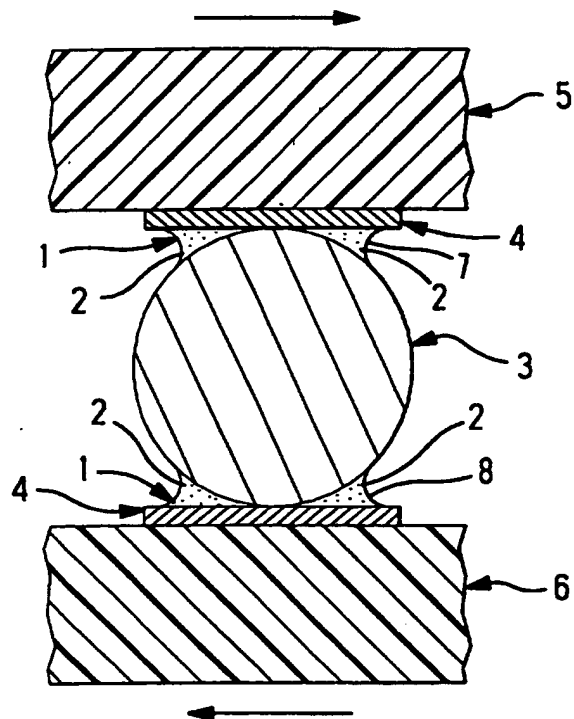


FIG. 1  
Prior Art

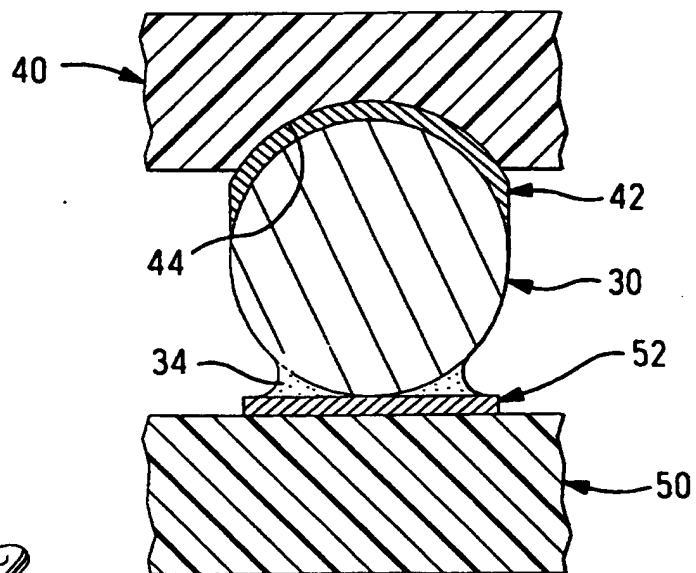
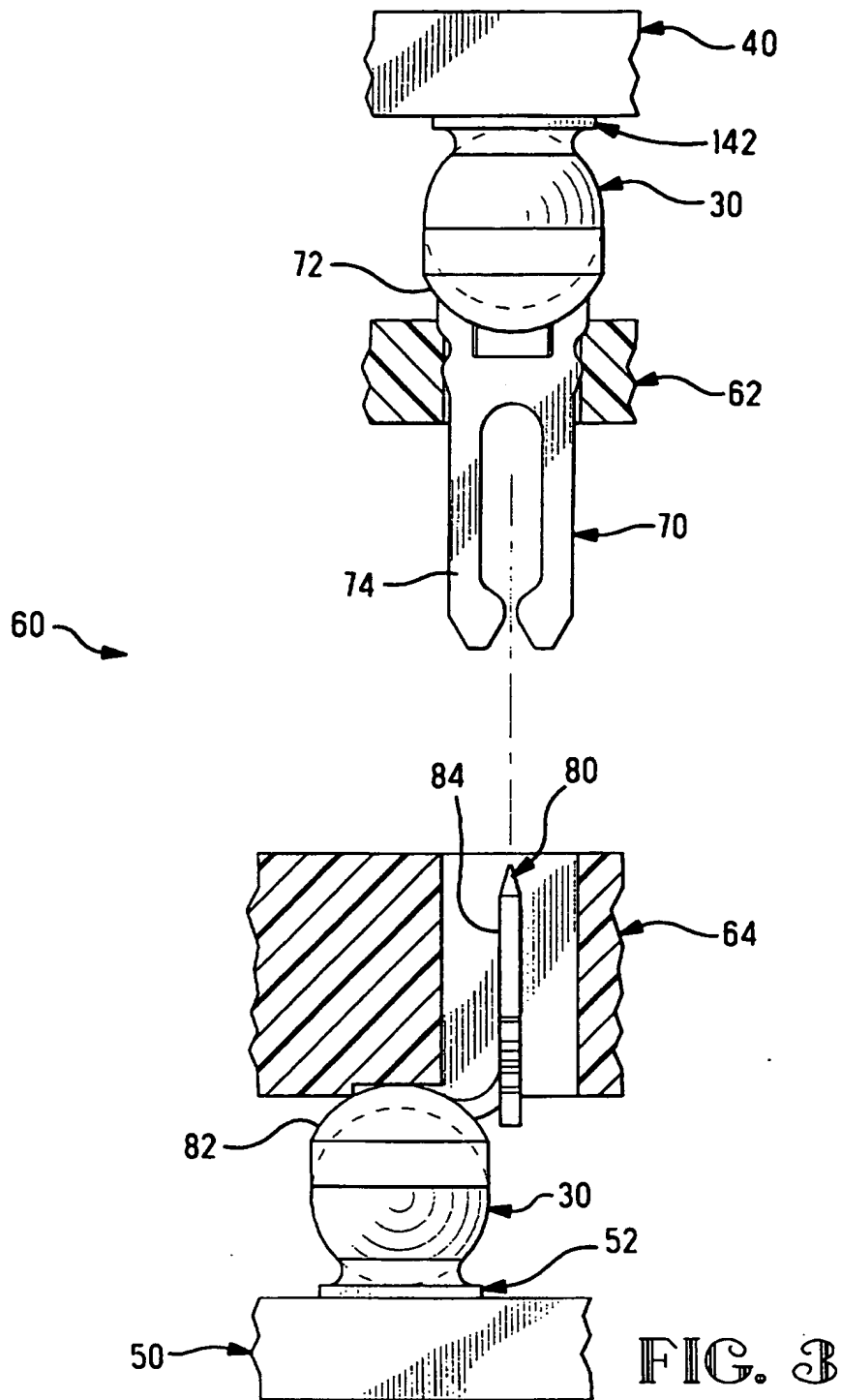


FIG. 2



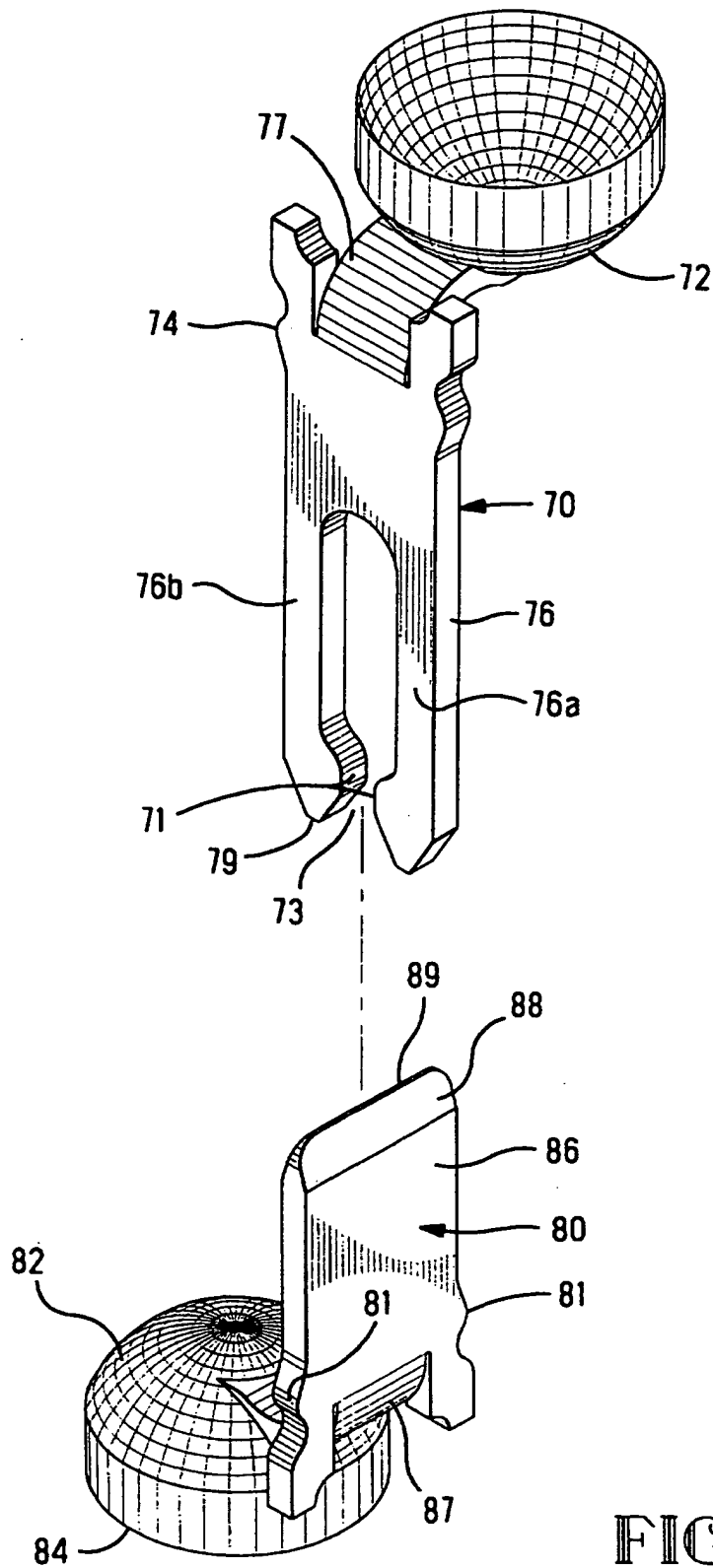


FIG. 4

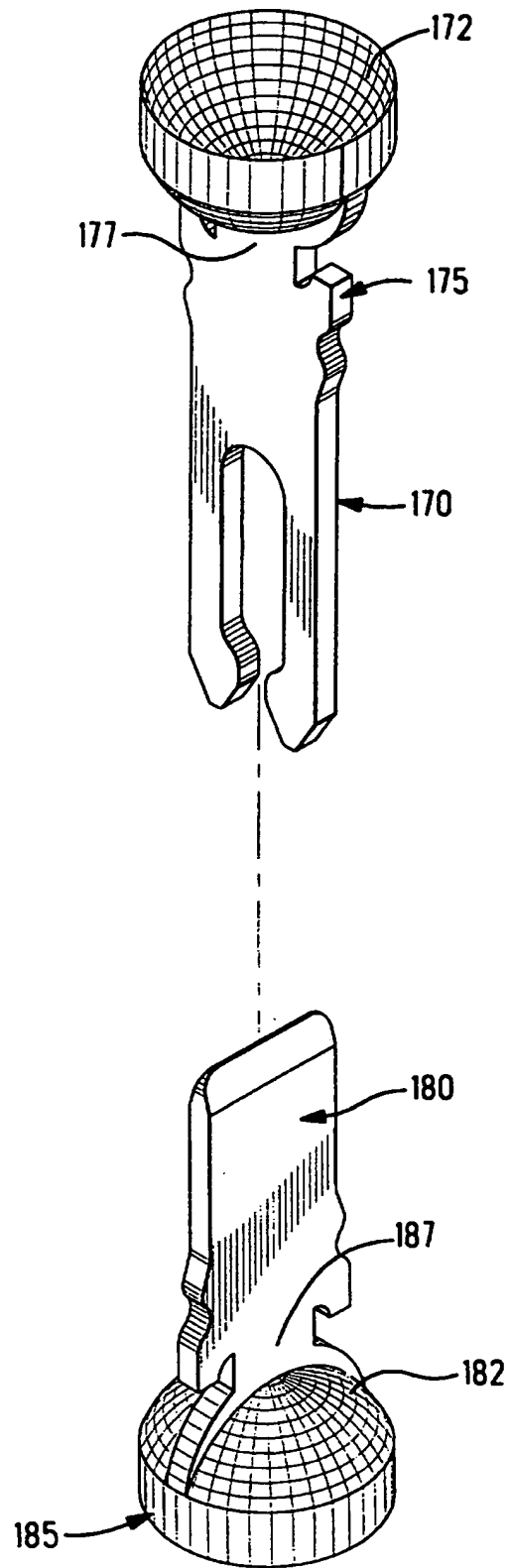


FIG. 5

-1-

METHOD OF ESTABLISHING ELECTRICAL  
CONNECTION BETWEEN A PAIR OF SUBSTRATES

This invention is related to electrical connectors and, more particularly, to a method of establishing electrical connections between two parallel substrates each having a plurality of contact sites.

Along with the continued movement towards increased use of surface mount technology (SMT) for mounting packaged ICs to substrates comes an increased need for higher numbers of I/O connections. Ball grid array (BGA) and land grid array (LGA) packages have been supplied with contact sites closely spaced around the perimeter of the package. In order to achieve higher numbers of I/O connections, while keeping the package size to a minimum, it has become desirable to populate a larger part of the surface of such a package instead of just the perimeter areas. The number of I/O connections can be further increased by populating the entire major surface along with further increasing the size of the package. A typical assembly process for a BGA package is disclosed by Ries et al. in IBM JOURNAL OF RESEARCH DEVELOPMENT, Volume 37, No. 5, September 1993. Figures 1 and 2 of that paper show a typical package in which a ceramic substrate is mounted to a printed circuit board through balls being connected to both the substrate and the card through eutectic solder joints. With the increased number of contact sites and package size comes increased failures due to thermal cycling during normal operation. This problem is identified by H. C. Choi et al. in IBM JOURNAL OF RESEARCH DEVELOPMENT, Volume 37, No. 5, September 1993 in a paper entitled, Solder Ball Connect (SBC) Assemblies Under Thermal Loading: II. Strain Analysis Via Image Processing, and Reliability Considerations. In the aforementioned paper, on page 653, Figure 2 shows a typical cross section of a solder ball and is reproduced in Figure 1 of the accompanying drawings.

At each interface, eutectic solder joints 1 form fillets 2 around the solder ball 3 at each contact pad 4 on both the module 5 and the printed circuit board 6. A typical failure mode is shown by Choi et al. at Figure 7 on page 657 of the paper whereby it can be seen that cracks appear at the fillets and propagate inward almost parallel to the interfaces. These failures occur in the area of the eutectic solder joint or the solder fillet 2.

It is believed that these failures occur because of the effects of thermal cycling involving the dissimilar materials of a circuit board and a typical module. These dissimilar materials have different thermal coefficients of expansion and therefore respond to thermal cycling by expanding or contracting at different rates. Also because heat is generated in only one of the two materials (i.e. the module), it expands before the other material reaches the same temperature. This results in a lateral displacement, in the direction indicated by the arrows in Figure 1 of the accompanying drawings, between the two which introduces a torque or a rolling motion on each ball. A resultant maximum tensile stress occurs at a point 7 (Fig.1) on a fillet 2 and a maximum compressive stress occurs at a point 8 on an opposite fillet. As package size is increased, the distance between balls at opposing ends (maximum ball separation) of the package also increases. The lateral displacement and torque experienced by each ball increases as the maximum ball separation increases. Therefore, as the package size is increased, a problem exists in that this torque causes cracks to initiate at the fillets 2 which are in tension. The cracks eventually propagate across the interfaces between the balls and substrates thus producing a failure.

This problem is addressed by providing a method of connecting a substrate such as a module to another substrate whereby the module is provided with a

plurality of concave-shaped contact sites located on a major surface thereof. These contact sites are profiled to receive balls therein. The balls are attached to both the concave contact sites of the module and corresponding  
5 contact sites on the printed circuit board by soldering.

Alternative embodiments show methods of providing separable electrical connections between such modules and printed circuit boards.

The invention will now be described by way of  
10 example with reference to the accompanying drawings in which:

Figure 1 shows a cross sectional view of a typical prior art connection between an IC module and printed circuit board.

15 Figure 2 shows a cross sectional view of a connection established between a module and a printed circuit board according to the present invention.

Figure 3 shows a cross sectional view of an electrical connector embodying the present invention.

20 Figure 4 shows a three-dimensional view of the contacts utilized in the connector of Figure 3.

Figure 5 shows a three-dimensional view of the alternate contacts for use in the connector of Figure 3.

Referring to the drawings Figure 2 shows a cross  
25 sectional view of an electrical connection established between a module 40 and another substrate such as a printed circuit board 50 according to the present invention. Here it can be seen that a module 40 is provided with a plurality of contact sites 42. It should  
30 be understood that while only one connection is shown here, the following description applies to each of the plurality of electrical connections established between the module 40 and the printed circuit board 50.



The module 40 may be a molded plastic package, a ceramic package, or any other package suitable for housing electronic devices and providing contact sites on a major surface thereof. This particular example shows a  
5 molded chip carrier package 40 having contact sites 42 each disposed in a respective concave section 44. The concave sections 44 are formed in the package 40 during the molding process or may be drilled after molding and the contact sites 42 are formed therein by conventional  
10 metallizing techniques.

The printed circuit board 50 has a plurality of contact pads 52 disposed thereon each corresponding to a respective contact site 42 of the module 40. As is well known in the art, each of the contact pads 52 is  
15 electrically connected to circuit traces on the printed circuit board 50.

The balls 30 establish an electrical connection between each of the contact sites 42 and their corresponding pads 52. These balls 30 may be formed of a  
20 lead-tin alloy (solder balls), copper, steel or other suitable conductive and solderable material. Also, they may be formed of glass or ceramic which is coated with a conductive and solderable material.

Assembly of the module 40 to the printed circuit  
25 board 50 will now be described in greater detail. First the pads 52 and contact sites 42 are coated with a low melting point solder. Next, the module 40 is populated with balls 30 such that one ball 30 is positioned and soldered inside each of the concave areas 44. The  
30 printed circuit board 50 is then placed over module 40 such that the array of balls 30 contact respective solder coated pads 52. The entire assembly is then heated to a temperature that would allow the solder to melt and form fillets 34. The entire assembly is then cooled and  
35 electrical connection is therefore established between each pad 52 and its respective contact site 42.

Referring now to Figures 3-5, alternative embodiments of the present invention are shown. In these embodiments, it is desirable to create a separable electrical connection between a pair of substrates, such as, a module 40 and a printed circuit board 50.

Referring first to Figure 3, a separable arrangement 60 is shown. The arrangement 60 is designed to connect the module 40 to the printed circuit board 50. Both the module 40 and the printed circuit board 50 are connected to respective connector housings 62,64 through a ball 30 to contact interface. While the module 40 and the printed circuit board 50 are permanently attached to respective contacts 70,80, these contacts are separable from each other.

Each of the electrical contacts 70,80 will now be described in greater detail with reference to Figure 4. The first contact 80 consists of a blade section 86 extending from a cup section 82. Each of these sections 82,86 are arranged generally perpendicular to each other. The blade section 86 is profiled to have a lead-in tapered surface 88 at a mating end 89. The blade section 86 extends from the mating end 89 to a bent neck 87 which joins the cup section 82 to the blade section 86. Retention barbs 81 are provided along opposing sides of the blade section 86. The cup section 82 has a ball-receiving cavity in 84. When viewed from the ball-receiving cavity 84, the cup section 82 is generally concave and may be partially spherical or parabolic in shape in order to engage a substantial portion of the outer surface of a ball 30 inserted therein.

The second contact 70 is profiled to have a similarly formed cup section 72 and a similarly formed bent neck portion 77. The bent neck portion 77 joins the cup section 72 to a fork 76. The fork 76 is profiled to have a pair of legs 76a,76b, each extending in a direction from the bent portion 77 toward a mating end

79. Each of the legs 76a,76b extend opposite each other to form a blade-receiving area 73 therebetween. Contact points 71 are disposed proximate the blade-receiving area 73 near the mating ends 79 in order to form the electrical interface between the first contact 80 and the second contact 70. Retention bars 74 are provided along opposing sides of the blade-receiving section 76 near the bent neck portion 77. These contacts 70,80 are insertable into their respective housings 62,64 by conventional techniques whereby the retention bars 74,81 engage sidewalls of respective openings of the housings 62,64 to retain the contacts therein. This is best shown in Figure 3.

Referring now to Figure 5, a pair of alternative contacts 170,180 are shown for use in the arrangement of Figure 3. These contacts differ from those of Figure 4 in that the bent neck portions 77,87 are replaced with straight neck portions 187,177. Also, the cup sections 182,172 are formed along the edge of a tab 175,185. These contacts 170,180 are similarly insertable into housings 62,64 of Figure 3 and provide the same electrical interface between the blade sections 86 and the blade-receiving sections 76 of the respective contacts.

An advantage of this invention is that the concave contact sites 42 or cup sections 72,82,172,182 serve to prevent the balls 30 from a tendency to roll as a result of a torsional load applied thereto. By utilizing the concave geometry, the printed circuit board to ball interface is subjected to only a sheer stress as opposed to a torsional stress. The sheer stress is evenly distributed across the interface such that the force per unit area applied to the fillets 34 is lower than that of the prior art arrangement. This will reduce a tendency for a crack to form at an edge of the fillet 34 and propagate inward through the interface.

CLAIMS

1. A method for establishing an electrical connection between a pair of substrates, comprising the steps of providing a first substrate having a concave contact site coated with solder, providing a second substrate having a complementary contact site coated with solder, placing a ball between the first and second substrates such that it engages both the concave contact site and the complementary site, and heating such that the solder flows to establish a connection between the substrates and the ball.
2. The method claimed in claim 1 wherein the ball is formed of a lead-tin alloy.
3. The method claimed in claim 1 wherein the ball is formed of copper or steel having a solder coating.
4. The method claimed in claim 1 wherein the ball is formed of glass or ceramic coated with a conductive material and overcoated with solder.
5. The method claimed in any preceding claims wherein the first substrate is an integrated circuit module which is formed of a ceramic material such that a plurality of concave contact sites are formed on a major surface thereof.
6. An electrical connection between a pair of substrates, wherein a first substrate has a concave contact site with a ball disposed inside the concave contact site and attached thereto, and a second substrate has a complementary contact site attached to the ball.
7. The electrical connection in claim 6 wherein the ball is formed of a lead-tin alloy.
8. The electrical connection claimed in claim 6 wherein the ball is formed of copper or steel having a solder coating.
9. The electrical connection claimed in claim 6 wherein

the ball is formed of glass or ceramic coated with a conductive material and overcoated with solder .

10. The electrical connection claimed in claim 6, 7, 8 or 9 wherein the first substrate is an integrated circuit module.

11. The electrical connection arrangement claimed in claim 10 wherein the integrated circuit module is formed of a molded material having a plurality of concave contact sites on a major surface thereof.

12. An electrical connector comprising a pair of housings each having a contact receiving opening for establishing an electrical connection between a pair of substrates, and a pair of contacts each of which is receivable into a contact receiving opening of a respective one of the housings, and each of which has an engagable terminal section disposed inside the respective contact receiving opening, a neck portion extending from the terminal section and a cup section extending from the neck portion, said cup section having a concave recess at a location opposite the neck portion.

13. The electrical connector claimed in claim 12 wherein one of the engageable terminal sections is a blade and the other is a fork.

14. The electrical connector claimed in claim 12 or 13 wherein the neck is bent such that it extends from the terminal section at approximately a right angle.

15. The electrical connector claimed in claim 12, 13 or 14 including a tab which extends from the neck, the cup section being formed in the tab along a major surface of the tab such that the recess is disposed along the major surface.

16. The electrical connector claimed in claim 12, 13 or 14 including a tab extending from the neck in a common plane, the cup section being formed in an end of the tab.

17. An electronic circuit module having a component mounted on a substrate which is receivable on another

substrate, the module comprising a plurality of contact sites disposed on a surface thereof, each contact site consisting of a metallized contact disposed in a cavity formed along the surface, the cavity being partially  
5 spherical or of other concave shape.

18. An electronic circuit module constructed substantially as hereinbefore described with reference to Figure 2 or Figures 3 and 4 or Figure 5 of the accompanying drawings.

10 19. A method for establishing an electrical connection between a pair of substrates, substantially as hereinbefore described with reference to Figure 2 or Figures 3 and 4 or Figure 5 of the accompanying drawings.

15 20. An electrical connection constructed substantially as hereinbefore described with reference to Figure 2 or Figures 3 and 4 or Figure 5 of the accompanying drawings.



Application No: GB 9806429.8  
Claims searched: 1, 6

Examiner: Howard Reeve  
Date of search: 9 September 1998

**Patents Act 1977**  
**Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK CI (Ed.P): H1K (KRG); H2E (EEA)

Int CI (Ed.6): H01L (23/488, 23/50); H01R (4/02)

Other: Selected publications

**Documents considered to be relevant:**

Category	Identity of document and relevant passage	Relevant to claims
X	GB 2165104 (SMITHS INDUSTRIES), see particularly the mounting of knobs 18, figure 4	1, 6
X	EP 0439137 (SUMITOMO), whole document	1, 6 at least
X	US 5435732 (ANGULAS ET AL), whole document	1, 2, 6, 7, 10 at least
X	IBM® Technical Disclosure Bulletin Vol 37, No 09, September 1994 (New York), "Pad on solder ball structure which allows for ball diameter variation", page 243	1, 6 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.